


# Sanitation utilities and fluoridation of water supply systems: an ecological study in Brazilian municipalities, 2008-2010\*

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## Abstract

**Objective:** to describe the characteristics of Brazilian sanitation utilities and municipalities according to the water supply system fluoridation situation. **Methods:** this was an ecological study using data from the National Survey of Basic Sanitation 2008, the Demographic Census 2010 and the Atlas of Human Development 2010. **Results:** of the 5,565 Brazilian municipalities, 60% had a fluoridation service; there was variation in fluoridation provision depending on the characteristics of the service providers and the municipality; the greater the coverage of water supply and sewerage and the higher the level of human development, the greater the provision of fluoridation ( $p < 0.001$ ); fluoridation provision was higher in municipalities where the sanitation utilities were mixed-capital companies (75%) and lower when the companies were private (27%) and also when the service was provided only by the municipal government (40%). **Conclusion:** there was an important dependence relationship between the characteristics of the companies and the provision of water fluoridation in Brazilian municipalities.

**Keywords:** Fluoridation; Sanitation; Sanitation Utilities; Public Health Policy; Ecological Studies.

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## Introduction

Fluoridation of the public water supply system is a public health intervention which consists of adjusting fluoride concentration with the aim of controlling dental caries in the population.<sup>1</sup> The strategy, recognized in the United States by the Centers for Disease Control and Prevention as one of the ten main Public Health measures implemented in the 20<sup>th</sup> century,<sup>2</sup> was recommended for the first time in Brazil at the 10<sup>th</sup> Brazilian Congress on Hygiene, in 1952. The following year, the municipality of Baixo Guandú, ES, deployed the measure and for this reason has been kept and observed as a pilot unit for evidence of the benefits of fluoride in caries reduction.<sup>3</sup> In 1974, water fluoridation became mandatory in Brazilian cities with water treatment plants, in compliance with Federal Law No. 6,050 dated May 24, 1974.<sup>3</sup>

*Fluoridation of the public water supply system is a public health intervention which consists of adjusting fluoride concentration with the aim of controlling dental caries in the population.*

The provision of fluoridation is directly related to the expansion of sanitation services, given that the existence of water treatment and supply plants is a requirement for its provision. An important milestone in the sector was the approval of the National Sanitation Plan (Planasa) in 1971, boosting the creation of the state sanitation companies, legally constituted as mixed-capital corporations, for the direct provision of these services to municipalities.<sup>4-6</sup> Whereas at the beginning of the 1980s, most of the world was already living an economic and political context marked by neoliberalism, Brazil only underwent this process at the beginning of the 1990s. Federal Law No. 8987/1995 authorized the participation of private companies in the sector, with federal government incentives for the privatization of these services via concessionary companies. In the 2000s, Law No. 11079/2004 regulated public-private partnerships in Brazil: a relationship between public and private entities, in which service concession was not granted in its entirety to private entities. Law No. 11445, approved in 2007, defined the basic principles and guidelines for access to federal resources, their

management, in addition to service regulation.<sup>4,5,7</sup> The current configuration of sanitation services provision reflects past policies and current neoliberal trends, bringing management characteristics specific to each location of the country, with important implications for fluoridation supply.

Between 1970 and 1990, urban water supply coverage increased from 54% to 90%.<sup>7</sup> During this same period, fluoridation coverage increased from 3% to 42%.<sup>3</sup> This growth in population coverage contributed to Brazil becoming in 2010 part of the select group of countries with low dental caries prevalence.<sup>8,9</sup> Data from the 2008 National Basic Sanitation Survey (PNSB) indicated that 60.6% of Brazilian municipalities had a water fluoridation service.<sup>10</sup>

Based on the population in each location, a longitudinal study involving 5,558 Brazilian municipalities showed that in less than a decade water fluoridation population coverage rose from 115 (67.7%) to 144 (76.3%) million inhabitants, representing an increase of 8.6% between 2000 and 2008.<sup>11</sup> The same study also found, in relation to the year 2000, that the characteristics of municipalities, such as population size and Municipal Human Development Index (MDHI), influenced the extent of fluoridation service provision.<sup>11</sup>

Knowledge is not available as to this influence with regard to the type of concessionary company. As such, more careful analysis of the dependence relationship of these variables and updating of available information is necessary.

This study aimed to describe the characteristics of the concessionary companies and municipalities according to their fluoridation of water supply systems.

## Methods

This was an ecological study taking all the 5,565 Brazilian municipalities existing in 2010 as its units of analysis.

The used data were taken from the 2010 Demographic Population Census, the 2008 National Survey of Basic Sanitation (PNSB) and the 2010 Atlas of Human Development. The Census is a source of information about the living conditions of the population in the municipalities, based on investigation of the characteristics of households and people living in them.<sup>12</sup> The PNSB survey aims to investigate the sanitation conditions of all Brazilian municipalities, based on information obtained

about the performance of the companies responsible for service provision.<sup>10</sup> The Atlas of Human Development presents indicators that reflect the characteristics of the population, education, housing, health, employment, income and vulnerability, with information retrieved from the 1991, 2000 and 2010 Demographic Censuses.<sup>13</sup>

Three variables were taken from the 2010 census:

- Coverage of the general water supply network

The only possible answer here is whether the service exists or not. The 'coverage of the general water supply network' variable was calculated based on the proportion of the number of permanent private households supplied by the general supply network in relation to the total number of permanent private households in the municipality. A permanent private household is considered to be one that was built exclusively for housing purposes and which, on the reference date, served as housing for one or more people. The percentage values of this indicator were grouped into quartiles.

- Coverage of the general sewage/surface water collection system

The only possible answer here is whether the service exists or not. The same calculation as used for the preceding variable was used to measure the coverage of the general sewage/surface water collection system. This service was considered to exist when pipes carrying wastewater and sewage from a bathroom or WC were connected to a collection system which in turn was connected to the main drain for the area, region or municipality, even if the system did not have a wastewater treatment plant. The percentage values of this indicator were grouped into quartiles.

- Population size

Considers the total number of residents in each household of the municipality on the date of the census. In order to describe it, population estimates for the year 2010 were separated into seven categories, according to the scale adopted by the Brazilian Institute of Geography and Statistics (IBGE): up to 5,000 inhabitants; 5,001 to 10,000; 10,001 to 20,000; 20,001 to 50,000; 50,001 to 100,000; 100,001 to 500,000; and more than 500,000 inhabitants.

Regarding the provision of water fluoridation, data on the existence of the service at least in the urban area of the municipality were extracted from the 2008 PNSB survey. A further three specific variables were selected regarding the nature of the service provider, thus resulting in the four variables listed below:

- Fluoridation provision of water supply system

Describes the existence or not of a water fluoridation service, at least at in the urban area of the municipality.

- The legal nature of the water supply service companies

This variable, when considered, refers to the legal structure under which company responsible supplying the service is incorporated. This structure was divided into six categories: (i) direct government administration; (ii) government agency; (iii) public company; (iv) mixed-capital company; (v) public consortium; (vi) foundation, private company or association. Based on these definitions of the company's legal nature, 1,848 municipalities had two, three or even four company classifications. In order to enable better understanding and for the purpose of avoiding categories with low frequency, the data on the legal nature of the provision of this service were organized into nine classes: (i) exclusive direct government administration; (ii) indirect government administration (government agency, public company or public consortium); (iii) only mixed-capital companies; (iv) only private administration (private company, foundation or association); (v) public mixed-capital companies (combination of two categories, one being mixed-capital companies and the other being direct government administration, public company, government agency or public consortium); (vi) private mixed-capital companies (combination of two categories, one being mixed-capital companies and the other being foundations, private companies or associations); (vii) direct government administration combined with any type of indirect government administration; (viii) direct public administration combined with private administration; and (ix) mixed-capital companies, being a combination of direct or indirect government administration and private administration.

- Administrative sphere to which the water supply company belongs

This variable identifies the entities responsible for water supply in municipalities. The type of administrative sphere was originally classified as federal, state, municipal, private, interfederative or intermunicipal. In the same way as the legal nature, the administrative sphere of the companies was recategorized due to the very small amount of municipalities included in some classifications (six municipalities with entities classified as federal and three with intermunicipal entities), and also because of existing combinations found. The following

categories were established: total exclusive state or federal entities; total exclusive municipal or intermunicipal entities; private entities; associations between public entities (two or three categories combined from among federal, state, municipal and intermunicipal entities); associations between public and private entities (two, three or four categories combined from among private entities and federal, state, municipal, intermunicipal or interfederative entities).

- Form of water supply service provision

This third legal nature variable shows which entities effectively provide the service. The form of provision was categorized according to the original template taken from the 2008 PNSB survey: the municipal government is the only provider; other entities provide the service; the municipal government and other entities provide the service.

Finally, only one variable from the 2010 Atlas of Human Development was used:

- Municipal Human Development Index (MDHI) for the year 2010

The MDHI is a composite measure of three dimensions of human development: longevity, education and income. The index varies within a scale of scores ranging from 0-1: the closer to 1, the greater human development is. The scores obtained are classified in the following way: very low (0-0.499); low (0.500-0.599); medium (0.600-0.699); high (0.700-0.799); and very high (0.800- 1).

The information for the variables was compiled into a single Microsoft Excel 2016 spreadsheet. Given the lack of fit to the normal curve, we used the Kruskal-Wallis test to verify a possible association between the presence of fluoridation, as a dependent variable, and the independent variable categories. This is a non-parametric test used for comparing three or more population groups regarding the nullness of the distribution functions, i.e., if the difference observed between groups is null. A p-value of less than 0.05 was used to reject the null hypothesis. We used SPSS version 21.0.0.0.

Given that the research only used public domain census information, there was no requirement for evaluation by the Research Ethics Committees/National Committee for Research Ethics system, in accordance with National Health Council (CNS) Resolution No. 510, dated 7 April 2016.

## Results

Of the 5,565 Brazilian municipalities, 60% had fluoridation services. Data were not accessible on the general water supply network (N=5), general sewage/surface water collection system (N=111) and legal nature, administrative sphere and form of service provision (N=34) in part of these municipalities; 89% had fewer than 50,000 inhabitants (N=4,957), 37% had their water supply treated by a mixed-capital company (N=2,056), 38% belonged to the federal or state administrative sphere (N=2,125) and 58% had their water supply services provided by other entities (N=3,220). In the year 2010, 40% of the municipalities were classified as having medium MDHI (N=2,233) (Table 1).

Regarding the coverage of water supply, the lowest quartile of cities showed up to 57% coverage, and the largest, above 84%. A quarter of the cities had no more than 1% coverage of a general sewerage network, and among the cities in the highest quartile, all of them had coverage over 56%. As seen in Figure 1, the higher the quartile for coverage of the general water supply network and coverage of the general sewage/surface water collection system, the greater the proportion of municipalities benefited by fluoridation ( $p < 0.001$ ).

The values obtained for water supply fluoridation provision were similar among the categories of municipalities with fewer than 50,000 inhabitants, whereby between 56% and 61% of these municipalities had provision of this service. Provision was greater in municipalities with a population exceeding 50,000 inhabitants, reaching a value of 87% among municipalities with more than 500,000 inhabitants ( $p < 0.001$ ) (Figure 2).

With regard to the MDHI categories, it can be seen that the higher the index, the greater the presence of fluoridation in the municipalities ( $p < 0.001$ ) (Figure 3).

Fluoridation provision was greater in the municipalities served by mixed-capital companies (75%) and lower when the concessionary company was private (28%;  $p < 0.001$ ). Different values were found between the state/federal spheres which accounted for 74% of fluoridation and the private sphere which accounted for 27% ( $p < 0.001$ ). Fluoridation provision was lower (40%) when the municipal government was the only provider of the service, in comparison with other forms of service provision observed which involved the participation of other entities in the provision of the service ( $p < 0.001$ ) (Figure 4).

**Table 1 – Absolute and relative frequency of Brazilian municipality (N=5,565) distribution according to the characteristics investigated**

Variables	Municipalities	
	N	%
<b>Water supply system fluoridation<sup>a</sup></b>		
Yes	3,351	60
No	2,214	40
<b>Population size (1,000 inhabitants)<sup>b</sup></b>		
<5	1,301	23
5-10	1,212	22
10-20	1,401	25
20-50	1,043	19
50-100	325	6
100-500	245	4
>500	38	1
<b>Municipal Human Development Index 2010<sup>c</sup></b>		
Very low (0-0.499)	32	1
Low (0.500;-0.599)	1,367	24
Medium (0.600-0.699)	2,233	40
High (0.700;-0.799)	1,889	34
Very high (0.800-1.000)	44	1
<b>Legal nature<sup>a</sup></b>		
Exclusive direct government administration	924	17
Exclusive indirect government administration	494	9
Mixed-capital companies only	2,056	37
Private administration only	209	4
Public mixed-capital company	974	17
Private mixed-capital company	309	6
Direct government administration combined with any type of indirect government administration	113	2
Direct government administration combined with private administration	186	3
Mixed-capital companies, combined with direct or indirect government administration and private administration	266	5
<b>Administrative sphere<sup>a</sup></b>		
Total exclusive state and federal entities	2,125	38
Total exclusive municipal and intermunicipal entities	1,383	25
Private entities only	208	4
Association between public entities	1,067	19
Association between public and private entities	748	14
<b>Form of service provision</b>		
Municipal Government is the only provider	943	17
Other entities provide the service	3,220	58
Municipal Government and other entities provide the service	1,368	25

a) Data from National Survey of Basic Sanitation 2008.

b) Data from Demographic Census 2010.

c) Data from Atlas of Human Development 2010.

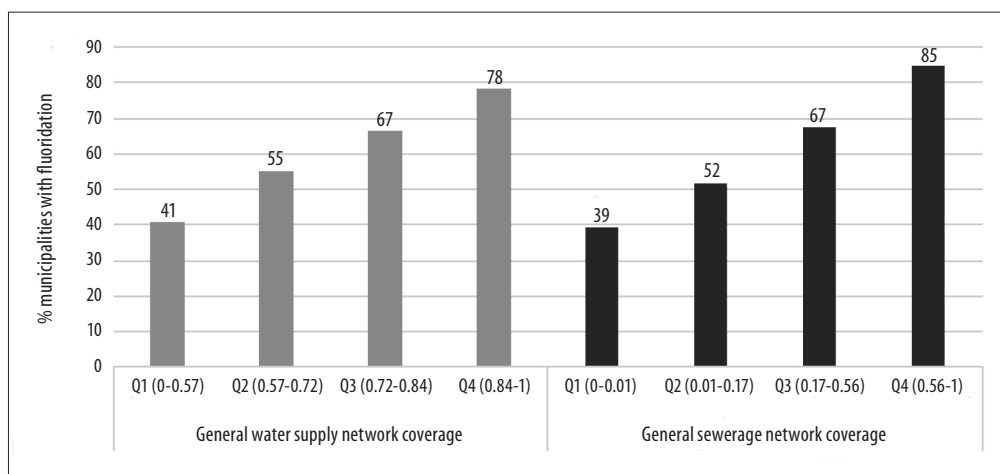
Missing Data: general water supply network (N=5); general sewage/surface water collection system (N=111); and legal nature, administrative sphere and form of service provision (N=34).

## Discussion

Fluoridation provision was more frequent in municipalities with higher categories of treated water coverage, population size, human development index, general sewerage network coverage and, moreover, where the concessionary companies were mixed capital companies, associated or not with other indirect government administration organizations and companies. Provision was less frequent in

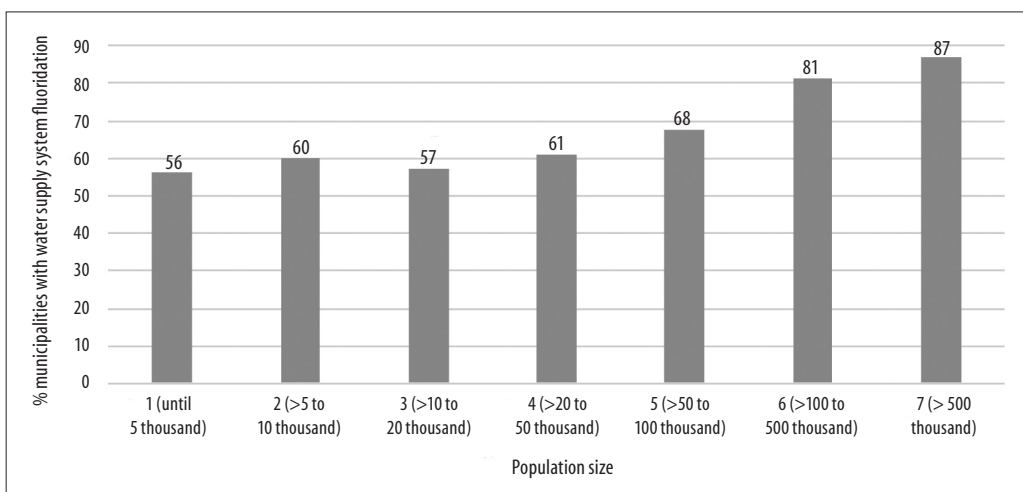
locations where the administrative sphere to which the concessionary companies belonged was the private sphere or exclusively municipal or intermunicipal, and where the municipal government was the sole provider.

The data used in this study are from 2008 and 2010. However, the information relates to a sector, namely –the sanitation sector, in which changes are of a medium- and long-term nature. The situation regarding fluoridation was obtained by means of a questionnaire administered by IBGE and answered

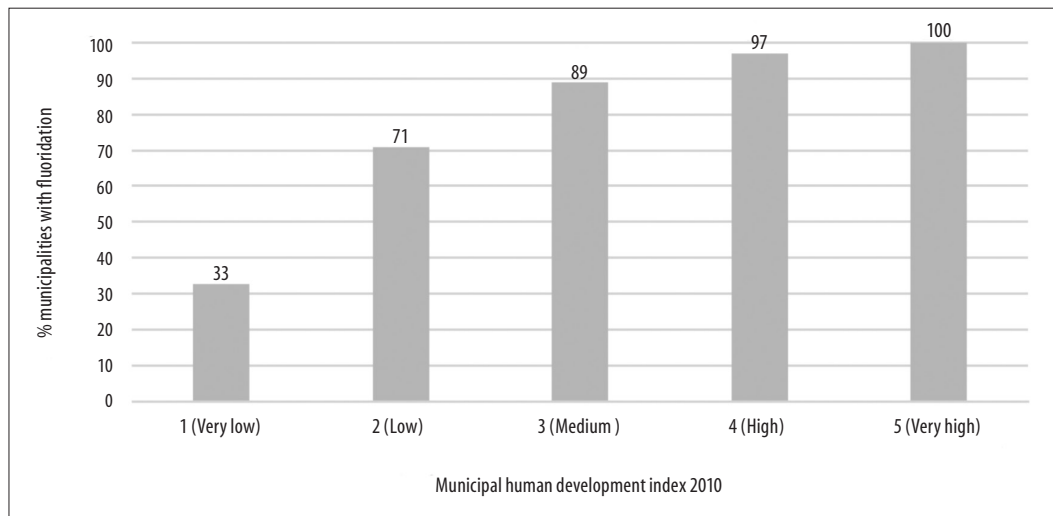


a) total number of municipalities with information available on coverage of the general water supply network.  
 b) total number of municipalities with information available on coverage of the general sewerage/surface water collection network.

**Figure 1 – Proportion (%) of municipalities with fluoridation service of water supply system according to the general water supply network coverage quartiles (N=5,560) and general sewerage/surface water collection network coverage quartiles (N=5,454 b), Brazil, 2008**



**Figure 2 – Proportion (%) of municipalities (N=5,565) with water supply system fluoridation (2008) according to population size (2010)**



**Figure 3 – Proportion (%) of municipalities (N=5,565) with water supply system fluoridation (2008) according to the municipal human development index (2010)**

by entities providing sanitation services. There is no other source of information available to provide more valid data. As previously mentioned, data is lacking on some variables in a small number of municipalities, but this does not imply changes to the associations found.

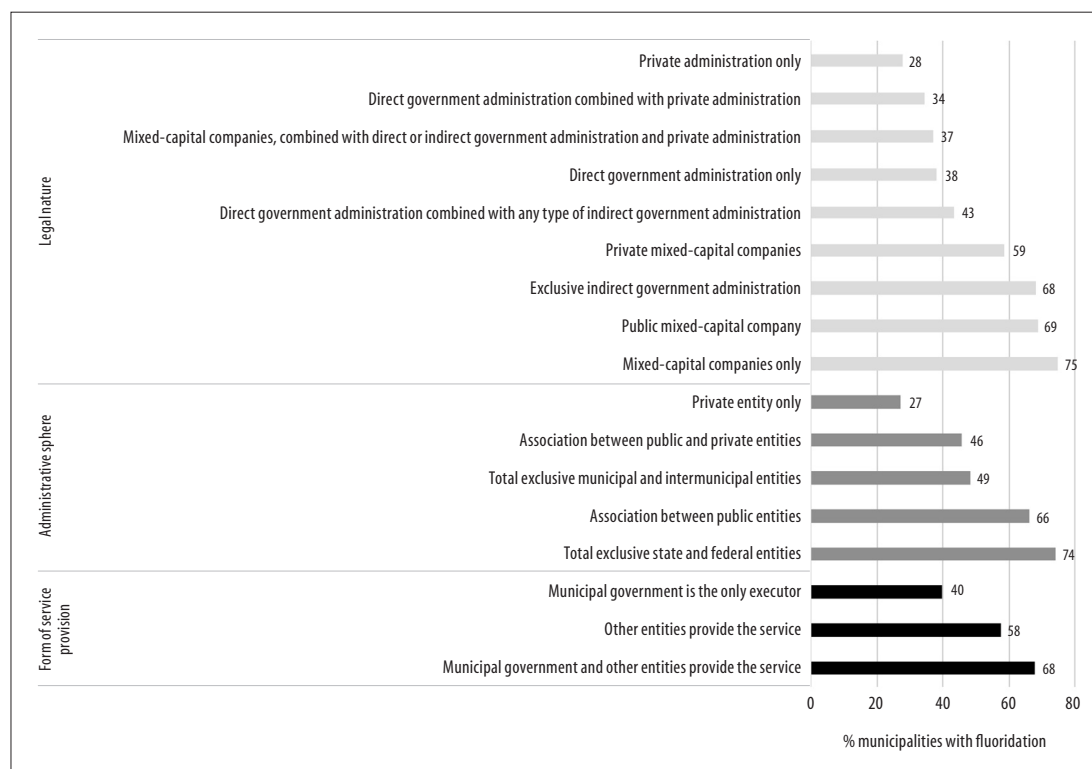
Cross-sectional and longitudinal studies have highlighted the regional inequality in the provision of sanitation services in Brazil,<sup>14,15</sup> and the results of our study show that this condition is reflected in the supply of fluoridation in Brazilian municipalities. The findings resemble those of research carried out with data from the year 2000, according to which municipalities with more than 50,000 inhabitants and those with higher MDHI also had higher fluoridation provision.<sup>11</sup> Results found in both studies suggest that the efforts made at the federal and state levels of government have not been sufficient to accelerate the expansion of this measure in municipalities with a very low or low MDHI, demonstrating the need to readjust deployment strategies.

It is known that the existence of a water treatment plant and a water supply network is a necessary condition for adjusting the concentration of fluoride in water. As there is a dependence relationship between the implementation of public policy and the existence of water treatment plants and water supply networks, it is recognized that the provision of this public policy could be greater: in 2008, 99.4% of the municipalities were supplying water by means of a general supply

network in at least one of their districts or part of them.<sup>10</sup> Thus, it is plausible to investigate the reason why fluoridation provision does not reach a larger number of municipalities, given that the cost of the measure is reduced when a water treatment and supply structure exists, and that the efficiency of the service is not affected.<sup>16</sup>

If on the one hand, the expansion of sanitation services in municipalities may be limited by the potential return on investment, owing to expansion being associated with the tariff revenue generated and the fact that there are upper tariff rates imposed by public policies,<sup>17</sup> on the other hand, a study on the efficiency of the sanitation sector in Brazil, using data from 369 service operators for the period 2000 to 2004, found that the provision of fluoridation services does not imply a significant increase in operational costs for the concessionary companies, regardless of their regional or local scope, or whether they are public or private.<sup>16</sup>

Another factor to consider is the investment capacity of the concessionary companies. A study on data from the National Sanitation Information System in 2010 showed that the public regional companies had higher levels of investment than private companies and local public companies.<sup>4</sup> Our study showed the leading role of the public sector in the provision of fluoridation. This result was expected in virtue of the history of public policies implemented in the sector. The entities characterized as mixed-capital companies (association



**Figure 4 – Proportion (%) of municipalities (N=5,531) with fluoridation service of water supply system, according to legal nature, administrative sphere and form of service provision, Brazil, 2008**

between public entities belonging to different spheres; or association between private and public entities) showed greater provision of fluoridation services in Brazilian municipalities.

Surveys conducted in different regions of the world have sought to compare the performance of public and private companies, after the sanitation sector was opened up to private enterprise. Data from household surveys carried out in 18 cities and provinces which have introduced some form of privatization in 28 control cities located in Argentina, Bolivia and Brazil, in the period from 1995 to 2001, showed that after privatization expansion of provision of this service to a level close to that observed in municipalities where this sector was managed by public companies.<sup>18</sup> Comparison of performance between the public and private entities in the provision of water services, based on the observation of 13 African countries in the year 2000, revealed that the improvement expected with privatization did not occur.<sup>19</sup> However, another study based on 50 concessionary companies from the Asia-Pacific region, carried out in the year 1995, found

private companies to be more efficient.<sup>20</sup> In addition, research in Saudi Arabia showed that technical and financial performance was outstanding in the first five years (2009 to 2013) after the privatization of the water supply system.<sup>21</sup> In China, the population served by private companies jumped from 8% in 1989 to 38% in 2008. This performance is attributed to strong central State control and bureaucratic coordination of public-private partnerships.<sup>22</sup>

Evidence presented by several studies published in the literature worldwide strongly point to the lack of a systematic intrinsic advantage in terms of efficiency in the provision of these services by the private sector. For this reason the expected benefits of the privatization process are not always achieved.<sup>23</sup> In this sense, when examining the experience of the remunicipalization of water supply services in the German capital Berlin, one's attention is drawn by the contingencies of the political process, capable of causing the breakdown of (i) the apparent consensus that - supposedly - characterizes the ideas surrounding privatization, and (ii) the notion that private providers would prioritize



the needs of populations, above their own interests, even in the face of countless possibilities for profit at their fingertips.<sup>24</sup>

In Brazil, following the decrease in the inflow of federal government investments in sanitation with effect from the year 1990, the investment of private capital as a solution for the sector began to be reconsidered. However, the historical legacy of the sector in terms of its ties with the Planasa is indisputable. Even if the authority granting concessions to operate in the sector is municipal, the provision of services by state companies has been found to be predominant, when compared to municipal and private companies: approximately 80% of the country's population was served by state public operators in 2002.<sup>25</sup> The notion of 'path dependency' has been used to explain the permanence of certain aspects of the sanitation policy in the last two decades and their strong resilience against the innovations proposed by governments of divergent political orientation between 1995 and 2007.<sup>6</sup> Analysis of the performance of Brazilian water supply concessionary companies in the period between 2002 and 2004, showed that public companies were more efficient.<sup>26</sup> A study analyzing the effect of governance on the dynamic efficiency of the water companies also found no robust gain in efficiency following the privatization of utilities.<sup>17</sup> When public companies were analyzed, there was more likelihood of households being connected to water and sewerage networks in municipalities served by government agencies.<sup>14</sup>

In addition to providing updated information as at 2010 available in the literature<sup>11</sup> on the relations between the provision of fluoridation and the characteristics of population size and human development in Brazilian municipalities, the main

contribution of this study has been to describe the characteristics of sanitation companies in Brazilian municipalities stating that they operate water fluoridation systems and, consequently, raise hypotheses about their relationships with the coverage of water supply networks and sewage/surface water collection systems for the population they serve.

We found a variation in the supply of fluoridation according to characteristics of the service providers and the municipalities, demonstrating that the type of concessionary company is important for the provision of fluoridation. The information produced showed significant associations of dependence between the characteristics of the concessionary companies and the provision of the fluoridation service, and can support future investigations on the effects of specific variables relating to concessionary companies and the provision of this public policy, either in view of the characteristics of the municipalities, or of those of the regions to which they belong. Furthermore, the results presented are an important source of information and evaluation of the impact of the more recent regulatory framework for sanitation (Law No. 11445/2007) regarding the implementation of the Brazilian public policy on fluoridation.

### Authors' contributions

Silva FB and Frazão P participated in the design of the study, data analysis and interpretation, writing and critical review of content and final approval of the version. Both authors declare that they are responsible for all aspects of the study, in the sense of ensuring that any issues regarding the accuracy or the integrity of any part of the study will be properly investigated and addressed.

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